Modal Analysis Characteristics of Steel and Concrete Low Rise Buildings

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Abstract— Modal characteristic of two different low rise buildings - concrete and steel is presented in this paper. Modal analysis is performed and mode results are given. The modelling and analysis is accomplished in SAP2000, the comparison of modal response of both steel and concrete building is given.
Key words: Modal Analysis, Steel, Concrete, Buildings

I. Introduction

Modes are considered to be inherent properties of a structure, and are determined through the material houses (mass, damping, and stiffness), and boundary conditions of the constitution. Each mode is defined by any ordinary modal or resonant) frequency, modal damping, and a mode form i.e. modal parameters [1-2].

If either the material or the boundary conditions of a constitution change, its modes will change significant. For illustration, if mass is brought to a constitution, it will vibrate otherwise [3-5].

The nonlinear static and dynamic method for seismic analysis of structures are more appropriate for concrete structure, concrete being a nonlinear material.

The nonlinear analysis has been performed in various studies [6-8] and is a recommended method of anlaysis.

II. Choice of Building Model

There are two types of buildings one is concrete low rise building termed (CL) and steel low rise (SL). The concrete building is designed as per IS 456:2000 and steel building is designed as per IS 800:2007. The sections are chosen to satisfy limit state of collapse/fracture.

The geometry of both concrete and steel building is kept same and is as shown in Fig. 1 and 2. The Fig. 1 shows plan of building and elevation is given in Fig. 2

The height of each storey is kept 3m as it is the common height taken in most multistorey residential building.

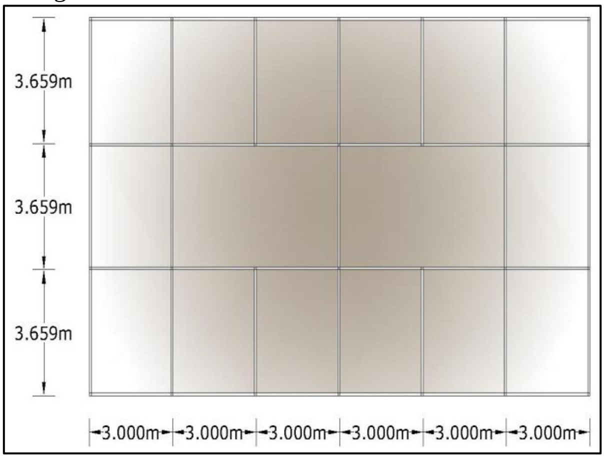


Fig. 1: Plan of low-rise building used in this study

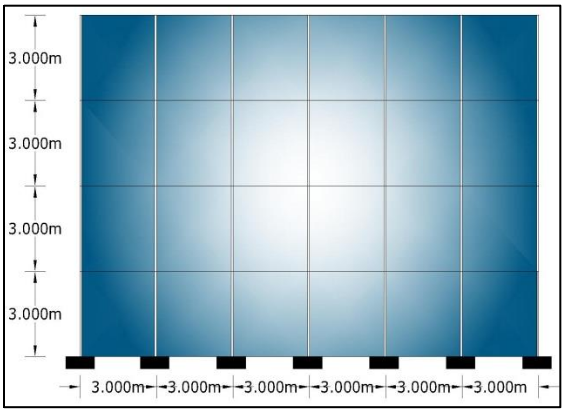


Fig. 2: Front elevation of low-rise building model

The building consists of four storey and floor are considered to be consisting of rigid diaphragm as a result there will only be 4 degree of freedom in lateral x-direction of building.

III. Modal Analysis method

Modal analysis mainly consists of treating the whole building as multiple degree of freedom with lumped masses at floor level.

The lumped mass model is then analysed for free vibration conditions.

The free vibration result is given in terms of natural period of vibration, mode shapes, eigenvalues, frequency etc. The natural period is an important criteria for evaluating the resonance condition on structure.

Mode shapes show how building will deflect in different modes of vibration.

In present paper, modal analysis is performed in SAP2000 software

IV. Results and Discussions

The results for modal analysis are reported in terms of mode shapes, modal displacement, time period, participation factors, and other characteristics and are given here.

A. Mode Shapes and Modal Displacements

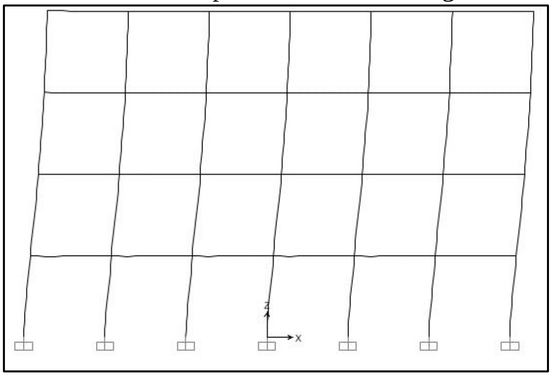
The modal displacement obtained by giving initial displacement to structure and noting the displacement at each degree of freedom. The modal displacements for both type of building is shown in Table 1.

On the basis of stiffness matrix and mass matrix, the eigen vectors are found out and are presented in terms of mode shapes. Since, building consists of 4 degree of freedom, hence four modes in lateral x-direction are obtained. These are shown in Fig. 3.

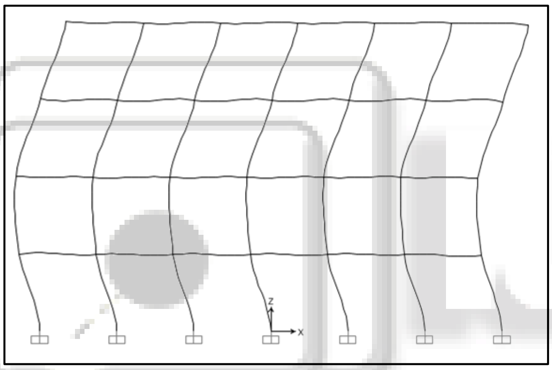
Story	Mode 1		Mode 2		Mode 3		Mode 4	
	CL	SL	CL	SL	CL	SL	CL	SL
Base	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.05	-	-	-	0.20	-	-	0.42

	97	0.1726	0.1602	0.4629	17	0.5825	0.1482	73
2	0.1336	-0.3860	-0.1862	-0.5373	-0.0455	0.1324	0.1931	-0.5575
3	0.1892	-0.5463	0.0075	0.0221	-0.1707	0.4923	-0.1639	0.4739
4	0.2178	-0.6286	0.2073	0.5987	0.1653	-0.4775	0.0882	-0.2554

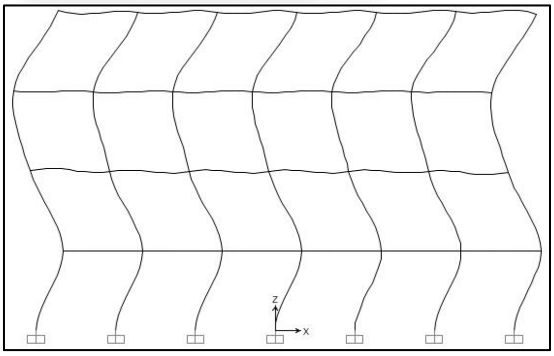
Table 1: Modal displacement for building models



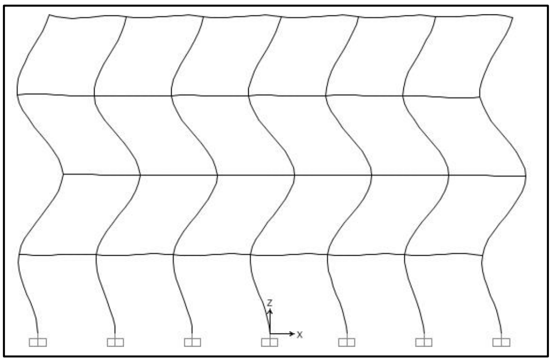
Mode 1



Mode 2



Mode 3



Mode 4

Fig. 3: Mode shape of structure

B. Time Period

For each term of matrix, there exists a characteristic root or eigenvalue which corresponds to period of vibration for that mode. The time period for both buildings at various modes are shown in Table 2.

As can be observed, due to less weight the time period of steel building is much less than concrete building (about 30% less).

Mode	Period (sec)	
	CL	SL
1	0.201504	0.139451
2	0.065933	0.045625
3	0.039298	0.027218
4	0.029696	0.020582
5	0.022345	0.014257
6	0.021684	0.013885
7	0.020631	0.013279
8	0.019382	0.012539
9	0.018275	0.011857
10	0.017544	0.011381
11	0.017263	0.01128
12	0.007896	0.005033

Table 2: Time period at various modes

C. Participation Factors

Participation factor show the contribution of particular mode in vibration of structure. If participation factor is more for first mode, building is considered to be significant in first mode.

Mode	Participation in x- direction	
	CL	SL
1	85.59%	85.62%
2	10.25%	10.23%
3	3.29%	3.29%
4	0.87%	0.86%

Table 3: Mode participation factors

D. Modal Characteristics

The various modal characteristics like cyclic frequency, circular frequency and eigenvalue are shown in Table 4.

Frequency	(Cyc/sec)	CircFreq	(rad/sec)	Eigenvalue	(rad^2/sec^2)
CL	SL	CL	SL	CL	SL
4.9627	7.171	31.181	45.057	972.28	2030.1
15.167	21.918	95.296	137.71	9081.4	18965
25.447	36.74	159.89	230.84	25563	53289
33.675	48.586	211.59	305.27	44769	93191
44.752	70.139	281.18	440.7	79064	194210
46.117	72.019	289.76	452.51	83961	204770
48.471	75.309	304.55	473.18	92752	223900
51.594	79.748	324.17	501.07	105090	251080
54.719	84.338	343.81	529.91	118210	280800
56.998	87.864	358.13	552.07	128260	304780
57.928	88.649	363.97	557	132470	310240
126.65	198.7	795.75	1248.5	633220	1558800

Table 4: Modal characteristics

V. CONCLUSION

Low rise buildings whether of concrete or steel are of primary type of building structures being constructed all over the world. In this study, two different types of building - concrete and steel but having same geometry are analysed dynamically. The result is in modal parameters.

The time period of steel building is found to be about 70% of that of concrete building. However, modal participation factor are found to be same for both buildings. Other modal characteristics are given also.

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